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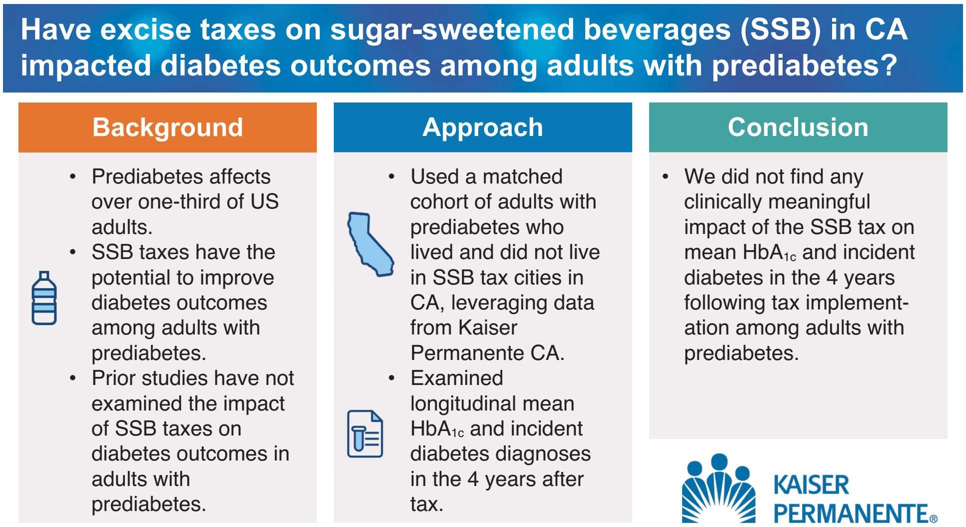

ARTICLE HIGHLIGHTS

- **Why did we undertake this study?**
  Excise taxes on sugar-sweetened beverages (SSBs) are policy interventions aimed at lowering SSB consumption that have the potential to delay or prevent the development of diabetes in individuals with prediabetes; however, we are not aware of studies evaluating this.
- **What is the specific question we wanted to answer?**
  Were SSB tax cities in California associated with decreases in longitudinal mean HbA_{1c} or reductions in diabetes incidence among adults with prediabetes?
- **What did we find?**
  We found no clinically significant association between SSB taxes and either longitudinal mean HbA_{1c} or incident diabetes among adults with prediabetes.
- **What are the implications of our findings?**
  The size of current California SSB excise taxes may not be sufficient to impact adults with prediabetes over 4 years.

The Effect of City-Level Sugar-Sweetened Beverage Taxes on Longitudinal HbA_{1c} and Incident Diabetes in Adults With Prediabetes

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ORIGINAL ARTICLE

OBJECTIVE

Prediabetes, which is a condition characterized by higher-than-normal blood glucose levels that are under the threshold for diabetes, impacts over one-third of U.S. adults. Excise taxes on sugar-sweetened beverages (SSBs) are a proposed policy intervention to lower population consumption of SSBs and generate revenue to support health-related programs, thus potentially delaying or preventing the development of diabetes in individuals with prediabetes. We leveraged data from Kaiser Permanente in California to examine the impact of SSB taxes in California on individual-level mean HbA_{1c} levels and rates of incident diabetes.

RESEARCH DESIGN AND METHODS

We compared two outcomes, mean HbA_{1c} levels and rates of incident diabetes, among a matched cohort of adults with prediabetes who lived and did not live in SSB excise tax cities, using outcomes collected in the 6 years prior and 4 years following SSB tax implementation. We used multivariable linear mixed effects models to analyze longitudinal mean HbA_{1c} and discrete-time survival models for incident diabetes.

RESULTS

We included 68,658 adults in the analysis. In adjusted models, longitudinal mean HbA_{1c} was 0.007% (95% CI 0.002, 0.011) higher in the tax cities compared with control individuals; while the estimated difference was statistically significant, it was not clinically significant (HbA_{1c} <0.5%). There was no significant difference in the risk of incident diabetes between individuals living in tax and control cities.

CONCLUSIONS

We found no clinically significant association between SSB taxes and either longitudinal mean HbA_{1c} or incident diabetes among adults with prediabetes in the 4 years following SSB tax implementation.

Prediabetes, which is a condition characterized by higher-than-normal blood glucose levels that are under the threshold for diabetes, impacts over one-third of US adults (1). Individuals with prediabetes are at high risk for developing diabetes, with an estimated annualized incidence of diabetes among individuals with prediabetes as high as 11 per 100 person-years (2,3).

Recent meta-analyses have demonstrated that higher consumption of sugar-sweetened beverages (SSBs) is associated with the development of type 2 diabetes (4,5). Excise taxes on SSBs are a proposed population-level policy intervention to lower the

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C.L. and M.A.S. are co-first authors.

consumption of SSBs and generate revenue to support health-related programs (6). SSB taxes have the potential to improve health outcomes by reducing consumption of sugar and obesity, thereby delaying or preventing the development of diabetes in individuals with prediabetes, as evidenced by trials (2,7,8). In 2015, Berkeley was the first city in the U.S. to levy SSB excise taxes, followed by three other California cities (Albany, Oakland, and San Francisco) in 2017. To date, seven U.S. cities have implemented SSB excise taxes, and the Navajo Nation has implemented an SSB sales tax (8).

Since the passage of SSB excise taxes in the U.S., several studies have examined the potential changes in costs, sales, and consumption of SSBs after implementation of the taxes and have provided evidence of higher prices and reductions in sales and consumption of SSBs attributed to these taxes (8). However, there have been few studies linking SSB taxes to health outcomes in U.S. adults (9–11 and D. Young, M. Hedderson, M. Sidell, C. Lee, D. Cohen, E. Liu, L. Barton, J. Falbe, G. Inzhakova, S. Sridhar, A. Voorhees, and B. Han, unpublished data). Among pregnant individuals in the U.S., SSB taxes were found to be associated with a 41.4% decreased risk of gestational diabetes, a 7.9% reduction in weight-gain-for-gestational-age *z*-score, and a 4.3% decreased risk of infants born small for gestational age (10). However, pregnant individuals comprise only a small proportion of U.S. adults. In the current study, we leveraged individual-level data from Kaiser Permanente (KP) Northern and Southern California, which represents over 8.1 million individuals, to examine the impact of SSB taxes in California on individual-level health outcomes. Specifically, we compared mean HbA_{1c} levels and rates of incident diabetes among a matched cohort of adults with prediabetes (balanced on age, race and ethnicity, sex, and BMI) who lived and did not live in SSB tax cities in the 4 years after taxes were levied. We hypothesized that individuals with prediabetes living in cities with SSB taxes would experience more favorable changes in HbA_{1c} and reduced diabetes incidence compared with individuals living in comparison cities.

RESEARCH DESIGN AND METHODS

Setting

We conducted a longitudinal two-arm natural experiment study including the treatment arm of four SSB cities and the control arm of 40 cities without SSB tax. All four SSB cities are located in the greater San Francisco area with unique socioeconomic and demographic distributions and KP health care coverage type. To account for the lack of randomization in this natural experiment, we matched each SSB city to 10 unique cities where SSB excise taxes were not implemented (control cities) on city-level demographic characteristics and KP coverage prior to tax rollout. The city-level matching procedure is described in detail in our prior work (12) and in the Supplementary Material. We used the Census Bureau's American Community Survey for yearly information on demographic characteristics of the California cities in which KP members resided. The person-year–level analytic data used in this study were retrieved from individual-level electronic health record (EHR) data from KP Northern and Southern California. This study was approved by KP Institutional Review Boards in Northern California (Oakland, CA) and Southern California (Pasadena, CA).

Cohort

We included adult KP members with prediabetes aged 20–65 years during the period 6 years prior to SSB tax implementation (i.e., 2009–2014 for Berkeley and matched control cities; 2011–2016 for the other three SSB tax cities and matched control cities) and 4 years following SSB tax implementation. We defined prediabetes as an HbA_{1c} level (closest to the SSB tax date) that was $\geq$5.7% and $\leq$6.4% using the 2021 American Diabetes Association (ADA) defined range for HbA_{1c} (12). Diabetes was defined as having at least two diabetes diagnoses in the EHR system, or two of these criteria: a HbA_{1c} value $\geq$6.5%, a fasting blood glucose $\geq$126 mg/dL, or a 2-h oral glucose tolerance test or random blood glucose $\geq$200 mg/dL. Further details regarding the algorithm we used for diabetes identification can be found in Karter et al. (13). We required that each individual had at least one HbA_{1c} record pre- and post-SSB tax intervention. We excluded individuals based on medical history (bariatric surgery within the last 5 years, metastatic cancer, palliative care, diabetes diagnosis prior to intervention year) and residential history (moved out of an intervention city, moved from a control city to another control city matched to an intervention with a different intervention year). For the analysis of incident diabetes, we further required continuous KP membership (enrolled in KP for $\geq$270 days per calendar year) in the year prior to tax implementation to ensure that individuals did not have a diagnosis of diabetes at the start of follow-up.

Key Variables

The exposure of interest was the implementation of SSB excise taxes, which occurred in 2015 for Berkeley and 2017 for Albany, Oakland, and San Francisco. We defined the intervention group as individuals who resided in one of the four SSB tax cities during the study period. We considered two separate outcomes: the first was yearly individual-level mean HbA_{1c} (averaged over each calendar year) over the study period (6 years pretax through 4 years posttax), and the second was incident diabetes diagnosis post-SSB tax intervention in the 4 years after tax implementation. Eligibility criteria ensured that each individual had repeated HbA_{1c} measurements before and after the SSB tax implementation time.

Covariates of interest included intervention city, race and ethnicity (derived from self- or family-reported information in the EHR), sex, age, Medicare/Medicaid status, mean BMI in the year prior to the tax intervention, mean BMI in the pretax period, value and year of last HbA_{1c} before the tax intervention, and a neighborhood-level poverty variable defined by the percentage of households within the census tract of an individual's residence that are at or below poverty level.

Statistical Analyses

Individual-Level Matching to Achieve Baseline Balance

To further account for potential imbalance in individual characteristics between the SSB cities and control cities, we matched each individual in an SSB city with one from the 10 corresponding control cities. We applied a conventional split matching procedure (14).

The individual-level matching procedure had two steps. We first partitioned individuals by the clusters of 11 cities (1 SSB city and its 10 control cities), race and ethnicity (non-Hispanic Asian, non-Hispanic Black, Hispanic [any race], non-Hispanic other/unknown, and non-Hispanic White), sex (male/female), and insurance status (KP plan versus Medicaid/Medicare) jointly.

This step yielded 80 subgroups. Next, in each subgroup, we performed a propensity score matching to further match on the remaining continuous covariates without discretization: age in 2011, average BMI in the pretax period, the last BMI in the pretax period, the year of the last BMI measure, average HbA_{1c} in the pretax period, the last HbA_{1c} in the pretax period, the year of the last BMI measure, and the household poverty rate in the census tract of the person's residence. This first step in our matching procedure ensured that the discrete covariates were perfectly matched. Balance of continuous covariates were verified in the second step within each subgroup and across all subgroups. The matching procedure was conducted by the MatchIt library in R 4.3.0 (15), where logistic regression was used to estimate the propensity score, and 1:1 propensity score matching was performed using nearest neighbor matching.

Difference-in-Differences Analysis of Longitudinal HbA_{1c}

We used a difference-in-differences approach to estimate the impact of the tax intervention on the HbA_{1c} outcome. Specifically, we fit a linear mixed effects model including categorical time (years since intervention), intervention group indicator, time-varying posttax indicator (with value 0 before the intervention and 1 after the intervention), interaction between the intervention group and posttax indicators, and intervention city as fixed effects. A random intercept for each individual was also included to account for the serial correlation among repeated measures. The effect of interest was the interaction term, which was interpreted as the difference in mean HbA_{1c} in the posttax period between individuals residing in tax cities compared with matched control individuals. As sensitivity analyses, we additionally accounted for the matched clusters through the use of nested random effects (individuals nested within matched sets) and adjusted for covariates used in the matching process (race/ethnicity, sex, age, Medicare/Medicaid status, mean BMI in the year prior to the tax intervention, mean BMI in the pretax period, value and year of last HbA_{1c} before the tax intervention, and neighborhood-level poverty) for tighter control of confounding.

Discrete-Time Survival Analysis of Incident Diabetes

In the analysis of incident diabetes diagnosis, individuals were followed from time of tax rollout to first occurrence of incident diabetes diagnosis, where loss to follow-up (e.g., loss of KP membership and death) and end of follow-up (4 years posttax) were noninformative censoring events. We estimated cumulative incidence for each year of follow-up using one minus the product-limit estimator for survival. We used a discrete-time survival model that included categorical time (posttax year) and intervention status, using a complementary log-log link function so that effects are interpreted as hazard ratios. We additionally accounted for the matched clusters by including random effects for each cluster and adjusted for covariates used in the matching process.

As secondary analyses, we conducted all analyses within strata of age and racial and ethnic group, which were preplanned analyses.

Data and Resource Availability

The data sets generated during and/or analyzed during the current study are not publicly available, as they contain protected health information of KP members, but are available from the corresponding author upon reasonable request.

RESULTS

Study Population

There were 34,329 matched pairs of individuals with prediabetes from the intervention and control groups for a total of N = 68,658 individuals included in the analysis. This comprised 18,429 female pairs (54%) and 11,118 (32%) Asian, 6,118 (18%) Black, 6,761 (20%) Hispanic, 1,330 (3.9%) other or unknown race/ethnicity, and 9,002 White (26%) matches. The median age at cohort entry was 54.0 (interquartile range [IQR] 44.0, 63.0) for control individuals and 55.0 (IQR 45.0, 63.0) for those in the tax cities. The cohort included 6,135 pairs (18%) with Medicare or Medicaid coverage and a mean of 10.1% neighborhood poverty rate with SD 8.5 and 8.9 for control individuals and tax city individuals, respectively. The last HbA_{1c} mean and SD were equal between groups (5.9%, SD 0.2), as was the last BMI average (29.1), although this SD varied between groups, with 6.2 for control individuals and 6.6 for the intervention. Standardized mean differences between demographic and clinical variables after matching were less than 0.10, with the exception of the year of last HbA_{1c} measure, which was 0.11 (Table 1). The mean (SD) number of HbA_{1c} measurements for individuals residing in tax and control cities in the pretax (1.9 [1.2] vs. 1.9 [1.1]) and posttax periods (2.2 [1.1] vs. 2.0 [1.0]) were comparable.

Difference-in-Differences Analysis of HbA_{1c}

In the 6 years prior to the tax implementation, mean HbA_{1c} was slightly higher in individuals in the tax cities, ranging from 5.86% to 5.93%, while people in the control cities were between 5.83% and 5.92% (Fig. 1*A*). Posttax, HbA_{1c} remained slightly higher for those in the tax cities, except for the tax year itself, where mean HbA_{1c} was 5.88% for the control individuals and 5.86% for the intervention (Fig. 1*A*).

The difference-in-differences analyses found very small and clinically unimportant associations between SSB tax implementation and mean HbA_{1c}. Specifically, the unadjusted analysis yielded an effect estimate difference of 0.007% (95% CI 0.002, 0.012) between intervention and control. After covariate adjustment, results were remarkably similar (Table 2). Similarly, estimated tax effects within race and ethnicity and age subgroups were not clinically meaningful (Table 2).

Incident Diabetes Discrete-Time Survival Analysis

In the 4 years following tax implementation, the estimated unadjusted cumulative incidence of diabetes increased approximately linearly for individuals in both the tax and control cities (Fig. 1*B*). In unadjusted and covariate-adjusted models, there was no significant overall association between the tax intervention and incident diabetes when comparing individuals with prediabetes residing in tax and control cities. Among subgroups of race and ethnicity and age, we similarly found no significant associations between SSB excise taxes and incident diabetes when comparing individuals with prediabetes in the cohort except for among Asian/Pacific Islander (Asian/PI) and Hispanic subgroups, where the fully adjusted hazard ratios are between 1.2 and 1.5 (Table 3 and Supplementary Fig. 2).

CONCLUSIONS

In this study, we investigated the impact of SSB excise taxes in California on individual-level HbA_{1c} levels and rates of incident

Table 1—Demographic characteristics of the propensity score–matched cohort of individuals with prediabetes who resided in tax and control cities during the study period

Characteristic	Control cities *N* = 34,329	Tax cities *N* = 34,329	Standardized mean difference
Sex			0
Female	18,429 (54)	18,429 (54)	
Male	15,900 (46)	15,900 (46)	
Race/ethnicity			0
Asian/PI	11,118 (32)	11,118 (32)	
Black	6,118 (18)	6,118 (18%)	
Hispanic	6,761 (20)	6,761 (20%)	
Other/unknown	1,330 (4)	1,330 (4%)	
White	9,002 (26)	9,002 (26%)	
Age at tax year (years)			−0.03
Median (IQR)	54.0 (44.0, 63.0)	55.0 (45.0, 63.0)	
Mean (SD)	52.6 (13.1)	53.0 (12.0)	
Medicare or Medicaid	6,135 (18)	6,135 (18%)	0
Household poverty rate (%)			0
Median (IQR)	7.0 (4.0, 13.2)	7.0 (3.5, 14.1)	
Mean (SD)	10.1 (8.5)	10.1 (8.9)	
Last HbA_{1c} (%)			0.01
Median (IQR)	5.9 (5.8, 6.0)	5.9 (5.8, 6.0)	
Mean (SD)	5.9 (0.2)	5.9 (0.2)	
Year last HbA_{1c}			0.11
2009	177 (0.5)	134 (0.4)	
2010	294 (0.9)	260 (0.8)	
2011	782 (2.3)	848 (2.5)	
2012	1,451 (4.2)	1,736 (5.1)	
2013	2,089 (6.1)	2,470 (7.2)	
2014	4,579 (13)	3,864 (11)	
2015	7,804 (23)	6,945 (20)	
2016	17,153 (50)	18,072 (53)	
Last BMI average (kg/m^2)			0
Median (IQR)	28.3 (25.0, 32.0)	28.0 (24.6, 32.1)	
Mean (SD)	29.1 (6.2)	29.1 (6.6)	
Year last BMI average (kg/m^2)			0.07
2009	105 (0.3)	92 (0.3)	
2010	120 (0.3)	117 (0.3)	
2011	1,682 (4.9)	1,568 (4.6)	
2012	1,962 (5.7)	1,816 (5.3)	
2013	2,038 (5.9)	2,115 (6.2)	
2014	3,321 (9.7)	3,354 (9.8)	
2015	4,183 (12)	4,931 (14)	
2016	20,918 (61)	20,336 (59)	

Data are *n* (%) unless otherwise indicated.

diabetes among adults identified with prediabetes prior to implementation of SSB taxes, among a large propensity score–matched cohort of adults who resided and did not reside in SSB tax cities during the study period. To our knowledge, this is the first study linking city-level SSB taxes to individual-level diabetes outcomes in a population of adults with prediabetes.

Overall, we did not find any clinically meaningful effect of the SSB tax from our analyses. Specifically, the mean HbA_{1c} outcome slightly, but not meaningfully, increased in the tax cities compared with control cities in the first 4 years after the tax implementation; the effect size was extremely small: while the difference in mean HbA_{1c} was statistically different from zero, the estimated effect of 0.007% (95% CI 0.002%, 0.012%) is far less than the clinically significant threshold of 0.5% (16). In addition, there was no significant overall effect of the tax intervention on incident diabetes. Note that, while the estimated adjusted hazard ratio for incident diabetes is not statistically significant, the 95% CI is consistent with a 1% lower through 14% higher risk of incident diabetes. However, these are not meaningful effects on the absolute scale, even at the high end of the CI: with estimated hazards (yearly probability of incident diabetes among those still at risk) in the range of 0.02 across all posttax years, a 14% increase corresponds to a hazard of 0.023. Thus, we found that the implementation of SSB taxes did not have a notable effect on diabetes outcomes among adults with prediabetes. In analyses among subgroups defined by race and ethnicity and age, we also found no clinically meaningful effects of SSB taxes on outcomes.

Given the relatively large sample size and the very small effect estimates, it is possible that city-level SSB excise taxes of $0.01 per ounce do not impact prediabetes progression at the population level over a 4-year period. This could be due to several factors. First, the SSB excise taxes of $0.01 per ounce is lower than the current recommendations by the World Health Organization of at least 20% increase in the retail price of SSBs that would lead to meaningful reductions of consumption of SSBs (6). Second, given that consumption of SSBs is a well-known risk factor for metabolic syndrome and type 2 diabetes (4), our findings suggest that individuals with prediabetes either did not reduce consumption of SSBs or compensated the reduced SSB consumption by other means, or that there was unmeasured or residual confounding. Third, there are methodological challenges to attributing changes in health outcomes to implementation of SSB excise taxes (17) that apply to this study, and it is possible that a 4-year posttax period was too short to detect a reduction in diabetes incidence in response to SSB consumption. A recent study estimated that 10-year risk of diabetes among individuals aged 45–85 years with prediabetes according to ADA criteria ranged from 14% to 20% among women and 9% to 19% among men, indicating that median time to progression is far longer than 10 years (18). On its own, the current SSB excise tax as a food environment measure to modify lifestyle may not be sufficient to impact adults with prediabetes.

One modeling study examined the potential effects of Mexico's SSB tax

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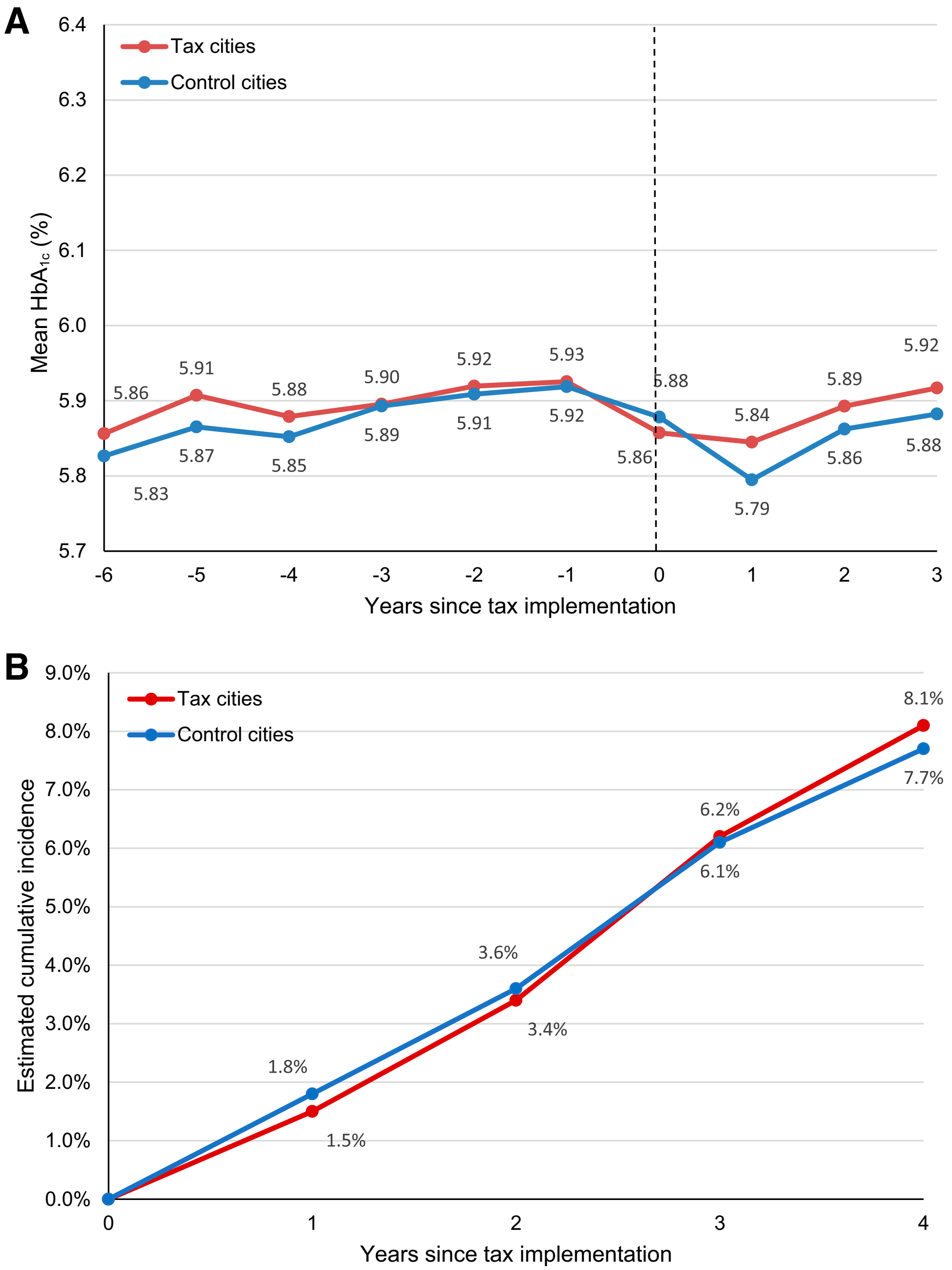

Figure 1—(*A*) Mean HbA_{1c} (percent) before and after tax implementation and (*B*) unadjusted cumulative incidence of diabetes in the 4 years following tax implementation among individuals with prediabetes residing in tax and control cities using a propensity score–matched cohort.

policy on consumption and incident diabetes. They estimated a 10% reduction in consumption would result in about 189,300 fewer diabetes cases over a 10-year period (19). Although our study only followed adults with prediabetes for 4 years after SSB excise tax implementation, we did not observe trends consistent with the modeling scenario in this subpopulation.

In the literature, estimated rates of progression to diabetes among individuals with prediabetes vary widely depending on the diagnostic criteria used for defining prediabetes, the population under study, and the length of follow-up, and thus are difficult to compare across studies (3). In this study, prediabetes was defined by HbA_{1c} of 5.7–6.4% (based on the 2021 ADA criteria), and the estimated 4-year cumulative incidence of diabetes among our cohort with prediabetes was 8% in both tax and control cities. While the seminal US Diabetes Prevention Program (DPP) trial estimated the 3-year cumulative incidence of diabetes to be 28.9% in the placebo group, much higher than was observed in our cohort, this discrepancy is likely due to differences in the criteria for defining prediabetes, which was based on impaired glucose tolerance plus fasting plasma glucose thresholds using the 1997 ADA criteria in the DPP, and the underlying study populations (e.g., mean BMI in the DPP was 34.0 ± 6.7 vs. 29.1 ± 6.2 in our study). Our findings are consistent with a recent systematic review of prospective studies examining

Table 2—Estimated intervention effect (mean difference in HbA_{1c} in percentage points) in the first 4 years after tax implementation and 95% CIs comparing individuals with prediabetes who resided in tax and control cities using a propensity score–matched cohort

	Intervention effect (95% CI)		
	Model 1	Model 2	Model 3
Full cohort	0.007 (0.002, 0.012)	0.007 (0.002, 0.012)	0.007 (0.002, 0.011)
Subgroup			
Race/ethnicity			
White	0.004 (−0.005, 0.012)	0.003 (−0.005, 0.012)	0.002 (−0.006, 0.010)
Asian/PI	0.015 (0.008, 0.022)	0.015 (0.008, 0.022)	0.015 (0.008, 0.021)
Hispanic	0.028 (0.016, 0.040)	0.028 (0.016, 0.040)	0.027 (0.015, 0.039)
Black	−0.002 (−0.017, 0.012)	−0.002 (−0.017, 0.012)	−0.002 (−0.017, 0.012)
Other	0.008 (−0.020, 0.036)	0.008 (−0.020, 0.037)	0.010 (−0.018, 0.038)
Age (years)			
18–25	−0.041 (−0.090, 0.009)	−0.041 (−0.090, 0.009)	−0.039 (−0.088, 0.010)
26–39	0.044 (0.026, 0.063)	0.044 (0.026, 0.063)	0.046 (0.027, 0.064)
40–55	0.008 (−0.001, 0.018)	0.008 (−0.001, 0.018)	0.007 (−0.003, 0.017)
55–65	0.000 (−0.007, 0.007)	0.000 (−0.007, 0.007)	−0.001 (−0.008, 0.006)
>65	0.007 (−0.001, 0.015)	0.007 (−0.001, 0.015)	0.007 (−0.001, 0.015)

The scale of the estimated effects is HbA_{1c} percentage points. Findings are based on linear mixed effects models for longitudinally collected HbA_{1c} that include random effects for each individual. Model 1 includes categorical time (in years since tax intervention), baseline intervention group indicator, time-varying posttax indicator variable, interaction between the intervention and posttax indicator, and intervention city. Model 2 additionally accounts for the within-matched set clustering via nested random effects. Model 3 adds to model 2 by adjusting for variables used in the propensity score matching for tighter control of confounding.

the development of type 2 diabetes in individuals with intermediate hyperglycemia that reported a pooled 4-year cumulative incidence of diabetes of 14% (95% CI 7, 23) among individuals with prediabetes defined using the same criteria as in our study (3).

The strengths of this study include a large, diverse study population, detailed EHR data, and rigorous methodological approaches (city-level and individual-level matching) to control for confounding. Despite these strengths, this study has limitations. First, we were only able to study outcomes in individuals who were members of KP, although KP membership in the tax and control cities that we considered was quite sizeable at around 30% (Young et al., unpublished data). Second, it is possible that exposure (residing in an SSB tax city) was subject to misclassification, as individuals may work, eat, shop, etc., in areas other than where they live. The approach we took was to introduce sufficient spatial separation between tax and control cities so that misclassification of the exposure should have been minor: 21 of the control cities were in Southern California with little to no possibility for exposure contamination, and the remaining 19 control cities in Northern California were geographically dispersed, with no control cities bordering any tax cities (Supplementary Fig. 2). Third, this study used data from a parent study (Young et al., unpublished data) that excluded individuals who moved from a tax city to a control city and vice versa. While these exclusions could be a potential source of selection bias, the extent of selection is minimal, with less than 3% of the original study population excluded because of moving between a tax city and control city. Fourth, we required that individuals included in the study had a least one HbA_{1c} record before and after SSB tax intervention, so that results are more generalizable to long-term members.

Moreover, a city-level tax policy may not be sufficient to change SSB purchasing and consumption behavior among those with prediabetes, as individuals residing in cities with SSB taxes are not

Table 3—Estimated hazard ratios and 95% CIs for incident diabetes diagnosis comparing individuals with prediabetes who resided in tax and control cities using a propensity score–matched cohort

	Hazard ratio (95% CI)		
	Model 1	Model 2	Model 3
Full data set	1.05 (0.99, 1.12)	1.08 (1.01, 1.16)	1.07 (0.99, 1.14)
Subgroup			
Race/ethnicity			
White	1.06 (0.93, 1.19)	1.09 (0.85, 1.41)	0.92 (0.70, 1.22)
Asian/PI	1.07 (0.97, 1.18)	1.24 (1.01, 1.51)	1.27 (1.01, 1.59)
Hispanic	1.13 (1.00, 1.27)	1.29 (0.96, 1.73)	1.57 (1.12, 2.20)
Black	1.01 (0.89, 1.16)	0.82 (0.62, 1.08)	0.90 (0.67, 1.23)
Other	0.93 (0.70, 1.24)	0.73 (0.39, 1.34)	0.95 (0.49, 1.85)
Age (years)			
≤39	1.34 (1.13, 1.58)	1.50 (>1.00, 2.25)	1.34 (0.84, 2.14)
40–55	1.08 (0.98, 1.19)	1.06 (0.87, 1.28)	1.20 (0.97, 1.48)
55–65	1.00 (0.91, 1.10)	1.13 (0.93, 1.38)	1.14 (0.92, 1.42)
65+	0.94 (0.81, 1.09)	0.92 (0.70, 1.20)	0.94 (0.70, 1.27)

Findings are based on discrete-time survival models for incident diabetes. Model 1 includes categorical time in years since tax rollout (to model the baseline hazard), intervention indicator variable, and intervention city. Model 2 additionally accounts for the within-matched set clustering through matched set random effects. Model 3 additionally adjusts for variables used in the propensity score matching for tighter control of confounding.

required to buy SSBs in their city of residence. Individual SSB purchasing and consumption behavior is a main causal mediator between SSB tax policy and the study outcome. However, we were not able to measure this individual-level mediator in this study. Lastly, we have estimated the average treatment effects among the treated, which may not be generalizable to the untreated cities, that is, the average treatment effect.

In conclusion, using individual-level data from over 60,000 California KP members and rigorous methods, we found no association between SSB taxes and 4-year longitudinal mean HbA_{1c} or incident diabetes among the subgroup of adults with prediabetes.

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